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THE VALUE OF PERCENTILE GRADES.

By Luther Gulick, M.D.

Read before the American Statistical Association, Feb. 10, 1893.

This paper might be called with greater propriety "A criticism of a certain use of the Percentile Grade system."

It is with considerable diffidence that I present this paper to you, as I am aware of the blunders which novices so commonly fall into, errors which might easily have been avoided had the work been done by those more experienced, or having had better training. I am keenly conscious that there are few fields which offer more hidden traps for unwary feet than does that of statistical study. I venture, however, as it seems that there are few others who are at work on just this phase of these problems, and I feel sure that your discussions will show errors that I, as well as others, may avoid in the future.

In estimating the value of work one must bear in mind the end for which it is done. The ends for which I have used Percentile Grades, and on which alone I can judge as to their value are,—

First, to show as far as may be the bony and muscular form, function, growth, and proportions of homogeneous wholes, individuals, and classes as compared to each other, and also to make comparison between the different items in the whole, the class, and the individual. I use the term "homogeneous wholes," for it is unnecessary to explain that only such can be tabulated to any purpose. Thus, it would be of no value (for the purpose which I have mentioned) to tabulate the measurements of men and women together.

Second, to ascertain if possible those proportions and functions of the body which should be sought after.

Third, to awaken and maintain interest in physical exercise among those who need it.

It will thus be seen at once that I exclude the ends for which the percentile grade system was designed, and for which it is surpassingly useful and reliable. I write simply from the standpoint of a teacher of physical education, who has used this method in the endeavor to secure certain definite results bearing on his work. The second aim is the one to which most particular attention has been directed.

During the past six years we in this country have been treated to a flood of anthropometric data, which if carefully prepared would have been proved sufficient to put the whole subject on a far advanced plane. It is to be regretted, however, that nearly all that has been done in this direction has been done without careful attention to method. The method which of late has been attracting the most attention is what seems to me an unjustifiable use of percentile grades. This scheme has been put to uses which not merely do not represent facts, but disproves them, and proves falsities to be true.

This method of statistical study in anthropometry has been adopted by our largest colleges, and has carried all before it. We have all been in the habit of having our measurements taken, then, and plotted on a chart, thus producing a line which purported to be a comparison of ourselves in all these different items with the normal standard, and which would enable us to compare each part of our body with every other part, in order to distinguish which parts were deficient. The whole being designated to stimulate us in our endeavors to acquire symmetrical forms according to this standard.

No explanation has ever been given as to why this method should show these standards, nor, as far as I know, have any questions been asked in this direction. Coming from such eminent sources it has swept all things before it, and blinded the eyes of all who might otherwise have felt inclined to examine it more critically.

We have before us a percentile chart. It is constructed as follows: A large number of different individuals are measured uniformly. These measurements are then sorted and arranged in rows under each item so that the highest shall be at one extreme, the lowest at the other. Sometimes this is done by making piles of the cards on which the measurements have been taken. This, it seems to me, is a cumbersome method, and does not afford opportunity for adding to these lists, nor verifying them at a later time. But, by arranging them in tabular form in a book, and making a dot for each measurement, these difficulties are overcome. Let us say that we have ten thousand individuals from whom the chart is to be constructed, and that we have already arranged them in the way mentioned. We are now working, we will say, on Girth of Head. Counting one hundred from the lower end, we find that the one-hundreth card reads 525 M. We then set down this figure immediately after Girth of Head and mark it one per cent. This means that out of the ten thousand individuals one hundred, or one per cent, are either equal to or smaller than that figure. We then count off four hundred more, making a total of five hundred, find our figure 534, place it next beyond one per cent, and label it five per cent. We count five hundred more, coming to 540. This is ten per cent of the whole: we put this down, and so we go on making the divisions or the per cents as large or as small as we please. We take next Breadth of Head, and treat it similarly, placing the figures directly beneath Girth of Head, so that the one per cents come in the same column. We thus get all the measurements of the body, or measurements of the individual. We include not merely linear measurements, but all which are capable of numerical representation, such as strength, as shown by the dynamometer, capacity of lungs, and the like. We now have a percentile chart, and any given horizontal set of figures is a set of percentile grades, and forms a percentile class.

This method of construction is the one in most common use, but is less accurate than that proposed by Mr. Francis

Galton. To use this chart we take the measurements of an individual in all the usual items, and make dots on the chart which correspond to the measurements of the individual in that item. We then connect these dots by a line This produces a more or less broken line, which represents the absolute measures of the individual, and which purports to represent his relations to the standard, and the relation of his parts to each other. Thus it is taken for granted that if a man's height falls under the twenty-five per cent class his weight should also fall there, the girth of his chest, and so on. The individual measured is now supposed to take this chart and endeavor to straighten his line. If the chest girth does not correspond with the rest of his line, he is to bring it up, if possible, to the standard by breathing exercises.

This scheme is on its face delightful, for it does away with the assumed fallacy that all should be the same height. In a measure it appears to make every man his own standard, so that a man's forearm shall be in proportion to his wrist, and not to that of some one else, and it gives us a convenient way of representing the relation of the individual to the whole.

Instead of taking an individual and thus plotting him, as it is called, we can take the mean measures of a class and plot them, showing how this class compares to this standard which has been secured.

We have now constructed our percentile table, and we have before us the percentile grades concerning whose value we are inquiring. We are told that the fifty per cent is identical with the mean. *By mean I refer to the value of a perpendicular in a binomial curve, which arising from its base extends to its summit.* Thus, *where there is no binomial curve there is no mean.* The mean involves the operation of the law of variation.

This percentile scheme, however, can be worked out for any class of objects whatever, whether they correspond or not to the law of variation. Thus we can get the percentile heights of all the chairs in this room, but it is highly improb-

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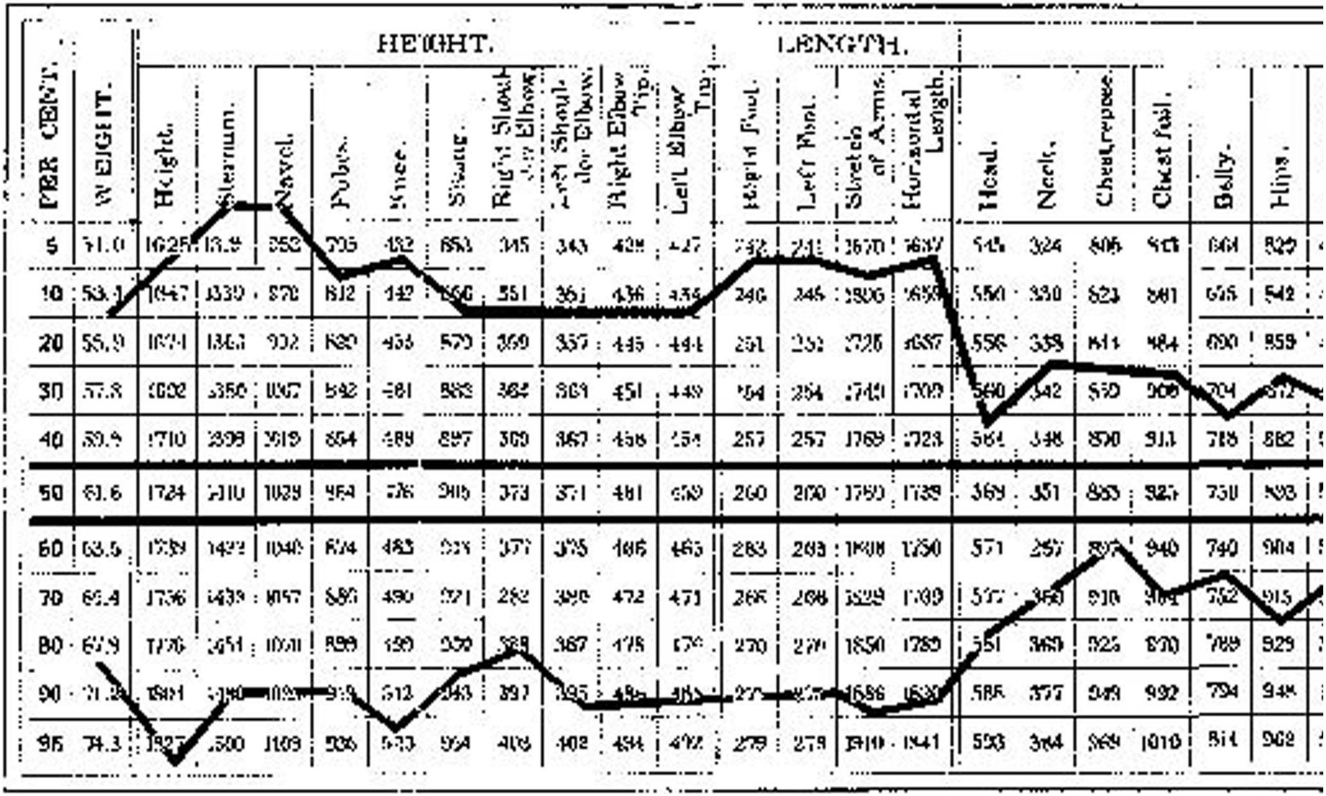
Compiled from 2230 measurements of Amherst College studs

Figures indicate Millimeters, Kilograms, Litres, ar

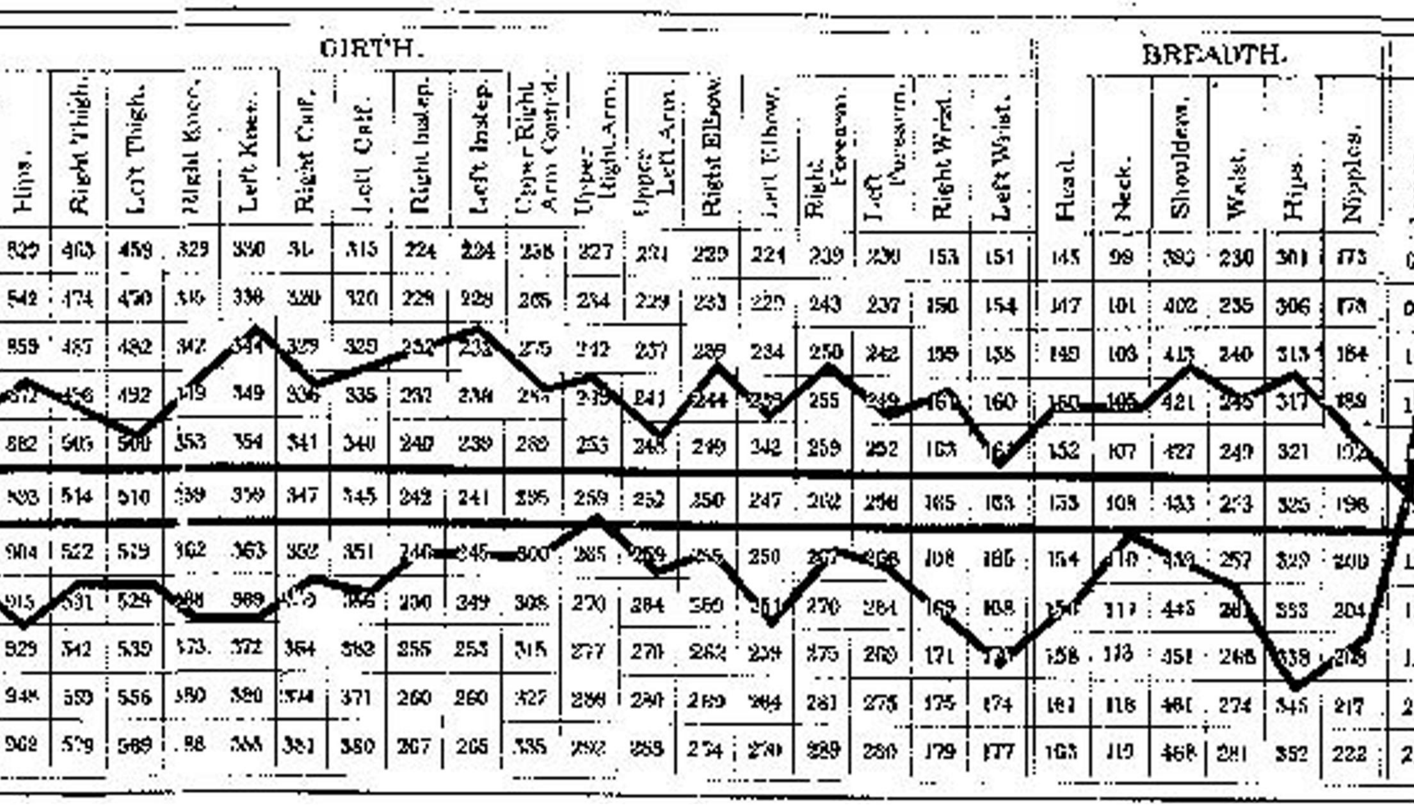


PER CENT.	WEIGHT.	HEIGHT.										LENGTH.									
		Height.	Sternum.	Navel.	Pubes.	Knee.	Sitting.	Right Shoulder Elbow.	Left Shoulder Elbow.	Right Elbow Tip.	Left Elbow Tip.	Right Foot.	Left Foot.	Stretch of Arms.	Horizontal Length.	Head.	Neck.	Chest repose.	Chest full.	Belly.	Hips.
5	51.0	1625	1319	953	795	432	853	345	343	428	427	242	241	1670	1637	545	324	806	848	664	829
10	53.4	1647	1330	970	812	442	860	351	351	436	434	246	245	1696	1659	550	330	823	861	675	842
20	55.9	1674	1343	992	820	455	870	360	357	445	444	251	252	1726	1687	556	338	844	884	690	859
30	57.8	1692	1350	1007	842	461	883	364	363	451	449	254	254	1749	1709	560	342	850	906	704	872
40	59.9	1710	1368	1019	854	469	897	369	367	456	454	257	257	1769	1723	564	348	856	911	718	882
50	61.6	1724	1380	1029	864	476	905	373	371	461	459	260	260	1780	1739	569	351	865	925	730	893
60	63.5	1739	1422	1040	874	483	[illegible]	377	375	466	465	263	263	1808	1750	571	357	897	940	740	904
70	65.4	1736	1439	1057	886	490	921	382	380	472	471	266	268	1829	1769	577	360	910	964	752	915
80	67.9	1776	1451	1070	899	490	930	388	387	475	479	270	270	1850	1780	551	369	925	970	769	929
90	71.2	1801	1480	1092	919	512	943	397	395	485	485	275	275	1886	1830	585	377	949	992	794	948
95	74.3	1827	1500	1109	936	523	954	406	402	494	492	279	279	1910	1841	593	384	969	1010	814	962
]

ROPOMETRIC TABL

D ON THE PERCENTILE METHOD

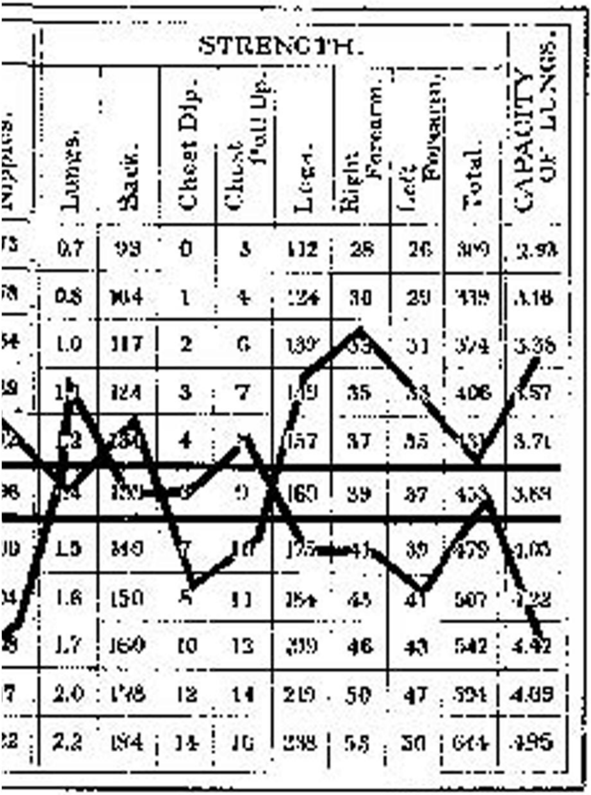
tudents between 1884 and 1891. Arranged according to the percentage as indi
s, and Units. The average age of the individuals observed is 20 years and 4 mon



GIRTH.																		BREADTH.					
Hips.	Right Thigh.	Left Thigh.	Right Knee.	Left Knee.	Right Calf.	Left Calf.	Right Instep.	Left Instep.	Upper Right Arm Contr'd.	Upper Right Arm.	Upper Left Arm.	Right Elbow.	Left Elbow.	Right Forearm.	Left Forearm.	Right Wrist.	Left Wrist.	Head.	Neck.	Shoulders.	Waist.	Hips.	Nipples.
829	463	459	329	330	316	315	224	224	258	227	231	229	224	239	230	153	151	145	98	390	230	301	173
842	474	470	335	338	320	320	229	228	265	234	229	233	229	243	237	150	154	147	101	402	235	306	178
859	487	482	342	344	329	329	232	233	275	242	237	238	234	250	242	159	158	149	103	413	240	313	184
872	456	492	349	349	336	335	237	238	284	249	241	244	238	255	249	161	160	150	105	421	245	317	189
882	505	500	353	354	341	340	240	239	288	253	248	249	242	259	252	163	161	152	107	427	249	321	192
893	514	510	359	359	347	345	242	241	295	259	252	250	247	262	256	165	163	153	109	433	253	325	196
904	522	529	362	363	352	351	246	245	300	285	259	255	250	267	258	168	166	154	110	439	257	329	200
915	531	529	368	369	359	356	250	249	308	270	264	260	251	270	264	169	168	156	111	445	261	333	204
929	542	539	373	372	364	362	255	253	315	277	270	262	254	275	269	171	171	158	113	451	266	338	208
948	559	556	380	380	374	371	260	260	327	288	280	269	264	281	275	175	174	161	116	460	274	345	217
962	579	569	388	388	381	380	267	265	335	292	288	274	270	289	280	179	177	163	119	468	281	352	222

LE

indicated at the left.
months.



	STRENGTH.								
Nipples.	Lungs.	Back.	Chest Dip.	Chest Pull Up.	Legs.	Right Forearm.	Left Forearm.	Total.	CAPACITY OF LUNGS.
73	0.7	99	0	3	112	28	26	309	2.93
78	0.8	104	1	4	124	30	29	339	3.16
54	1.0	117	2	6	139	33	31	374	3.36
89	1.1	124	3	7	149	35	33	406	3.57
02	1.2	130	4	8	157	37	35	431	3.71
98	1.4	[illegible]	6	9	160	39	37	453	3.89
00	1.5	140	7	10	175	41	39	479	4.05
04	1.6	150	8	11	184	43	41	507	4.22
8	1.7	160	10	13	199	46	43	542	4.42
7	2.0	178	12	14	219	50	47	594	4.69
22	2.2	194	14	16	238	53	50	644	4.95

able that we could get a true binomial curve from these heights, since we might easily find that the shortest or the highest chairs were the most numerous (or were more numerous than those of any other height). The percentile scheme implies that there is always a central standard. If we could measure all the bricks in the country we should find the great majority of them were a certain size than which there are few smaller, the variations being almost entirely towards the larger sizes. We could very easily arrange their dimensions in a percentile chart, but if we constructed a curve with them we should find that instead of being symmetrical the class of smallest bricks would have in it the greatest number, and from there it would slope down, by various jerks, to the largest brick that was made. I once arranged a percentile table of the age of members of a certain Young Men's Christian Association. The age limit was 17. I was able, however, to grade them off very nicely, bringing the 50 per cent up to about 22. I then constructed a curve, but found that there were more individuals at 17 than at any other point, 18 coming next, 19 next, and all forming a regularly descending line, though not a binomial curve. Thus, this objection is simply that we must construct the curve for each item, or in some way establish that it is a true binomial curve before we have any right to make it conform to the percentile scheme. This is the first difficulty.

Second, it is assumed that the various items are so related that taking any given percentile grade in each we shall have a set of numerical values that will represent the symmetrical man. Thus because five per cent of men have a weight of 51 kilos, and five per cent of men have a height of 1.625 M., and five per cent of men can lift but 112 kilos, therefore the individual man who is 1.625 in height ought to weigh 51 kilos, and should be able to lift but 112 kilos. This can perhaps be answered by an examination of a percentile table, which is included on an accompanying sheet.

It is only fair to Dr. Hitchcock to say that he apparently has fallen into the error that is under discussion, for the claim that it is a "standard of symmetry" is not made for it. This particular table is used in preference to those from elsewhere, inasmuch as the *same* measurements from which it was constructed have also been treated in other ways, and thus form an unusual opportunity for the comparison of methods.

At the extreme left is the column indicating the per cents. Thus we notice under five per cent weight 51 kilos, and height 1.625 M. This means that five per cent of the total number examined fell below 51 kilos in weight, and below 1.625 M. in height. Looking along further in the same column we find under chest dip 0, and under chest pull up 3. Thus five per cent of men cannot dip at all, and can pull up 3 times or less. There is no question that each of these items gives us a definite and useful fact. It is now assumed by some that because a given man weighs 51 kilos that therefore he ought to be but 1.625 M. in height, pull himself up but three times, and not dip at all. In other words, that these figures in any given column of per cents represents the symmetrical standard. In Table II, column B, we find the measurements of all men who are from 1.620–1.630 in height averaged. Note that they can dip 8.8 times, and pull up 10.6. Turn again to the percentile and note that the man 1.827 M. in height can or should, if the assumption is true, dip 14 and pull up 16 times. Turning again to Table II, note column C, which gives the average measurements of the man between 1.820 and 1.830 in height. The man of this height can dip but 5.6 and pull up 8.1 times. Thus we secure two sets of results. The man 1.625 in height pulls up either 3 or 10.6 times, and the man 1.825 in height pulls up either 16 or 8.1 times, according to the method employed in tabulation.

It will doubtless be objected that only items that are more closely related than are height and strength should be tabulated into percentile classes and be expected to produce

TABLE II.

		A.	B.	C.
WEIGHT		61.2 Kilos.	54.1	68.3
STATURE		M. M. 1,725	1,620	1,820
HEIGHTS.	Sternum	1,410	1,300	1,480
	Navel	1,030	962	1,090
	Pubes	860	810	919
	Sitting	903	869	939
	Knee	476	439	519
LENGTHS.	R. Sh. Elbow	373	351	395
	L. Sh. Elbow	371		
	R. Elbow Tip	461	436	486
	L. Elbow Tip	459		
	Right Foot	260	244	274
	Left Foot	259		
	Stretch of Arms	1,780	1,690	1,890
	Horiz. Length	1,732	1,640	1,820
GIRTHS.	Head	572	562	583
	Neck	349	340	356
	Chest, repose	880	854	898
	Chest, full	927	888	953
	Belly	724	703	748
	Hips	893	864	922
	Right Thigh	517	500	525
	Left Thigh	512		
	Right Knee	361	341	368
	Left Knee	359		
	Right Calf	359	332	355
	Left Calf	349		
	Right Instep	245	231	246
	Left Instep	242		
	R. U. Arm	257	246	261
	L. U. Arm	253		
	R. U. A., cont.	295	280	300
	Right Elbow	251	240	254
	Left Elbow	247		
	Right Forearm	267	250	266
	Left Forearm	261		
	Right Wrist	166	161	170
	Left Wrist	165		
BREADTHS.	Head	155	151	156
	Neck	108	106	109
	Shoulders	430	418	440
	Nipples	198	192	206
	Waist	250	245	263
	Hips	323	315	341
STRENGTHS.	Lungs	Kilos. 1.5	1.4	1.1
	Back	137	126	147
	Legs	166	147	174
	R. Forearm	41.5	33	42
	Left Forearm	38.1		
	Dip	No. of times. 6	8.8	5.6
	Pull Up	9	10.6	8.1
LUNG CAPACITY		Litres. 3.77	3.25	4.43
PILOSITY		Tenths of Body. 2.25	2.4	2.06

straight lines with symmetrical individuals. To answer this I refer you back to Table I.

I have taken Dr. Hitchcock's averages for the men, 1.62 and 1.82 M. tall, found in Table II, Columns B, C, and plotted them on this percentile chart (Table I). You notice that they do not correspond at all in certain particulars; in other particulars they correspond very well. I have rearranged the items on the chart to a slight extent, so that all the bone lengths come together; otherwise the chart is in its original condition. It is first to be noted that the line of the man 1.620 M. in height pursues a course in the main between five and ten per cent as far as Horizontal Length. Here it takes a sudden drop and does not again reach the ten per cent line. Notice, similarly, that the man 1.820 M. in height (the lower line) makes a line similar in its general outline to the shorter man, but reversed from it. From this it is easy to deduce that the bone lengths vary with the height, but that the girths do not. Tall men have smaller muscles in proportion, and short men larger muscles in proportion, than would be indicated if the percentile line was accepted as the standard of symmetry. This assumption can be shown in a humorous way by the following illustration: Because ten per cent of men wear full beards, and ten per cent also weigh 157 pounds or over, it does not follow that the man who wears a full beard should weigh 157 pounds or over. The relationship between these two items must be established before any such deduction could be made.

Third. Another difficulty with this use of the percentile method for the objects stated is that it assumes that there are no different types, that there is but one standard of symmetry. This would be like the assumption that there is but one standard for all different nationalities. If we could measure all the individuals in the world, or at least a large proportion of them, we should no doubt get some interesting statistics, but to measure an indefinite number of African pygmies and Europeans and construct a percentile table from them would be on its face absurd. We have different types of men, shown by the various forms of old Greek statues, any of whom may be said to be symmetrical. The same may be said of our modern athletes.

More important, perhaps, than this is that there seems to be a difference in the proportions of tall men and short men, that is, growth in girth of bone and muscle does not seem to correspond with growth in length of bone, so that as a matter of fact instead of finding that tall men are simply big little men we find that they have other standards, and are not similar in proportion to short men. Any scheme of statistical study which ignores this, or which renders its proof impossible, is useless for the purpose mentioned at the opening of this paper.

There is, however, another view that should be taken. The mean and the percentile scheme properly used show us what we are. These values have a wonderful stability and certainty. But we are told by some that this mean also tells us what *we ought individually to be*, giving us the ideal (not merely the type) of the race, the goal that is before us, and toward which we should all press.

If we lived under ideal conditions, then it would be true that the mean would represent the central standard; but we are not under ideal conditions, and securing the mean from us, as we are now, and affirming that it is the standard to which we should conform, would be like taking the mean of ten thousand cases of dyspepsia and saying that all should conform to the mean of these. It would be like taking the measures of the waists of ten thousand college girls, who notoriously do more mental and less physical work than they should, a great majority of whom have more or less constriction at the waist, and saying that this represents the standard around which the world revolves. It represents, and will continue to represent, the actual condition of things, and will not change from century to century *until the conditions change.* Only by different conditions can we get a different mean.

It is the business of all reformers to spur people on, not towards a mean, not towards a central standard of what people already are, but towards an ideal. If it were true that the moral sense of as many people is too acute as it is true that the moral sense of the people is too blunt then the mean would represent the ideal, but who would wish to say that the mean of the moral sense of the people (if he had a method of ascertaining it) would represent the ideal toward which we should struggle?

It follows, then, that no matter how accurate the mean, nor how desirable the percentile, scheme for the giving of light on certain difficult aspects of anthropology, it is of doubtful value, when used as indicated, for the securing of an ideal standard which shall be of practical value in directing physical exercise.

I believe that it is incumbent upon those who criticise to suggest something better. I would suggest, then, that methods of anthropometric statistical study should be adopted which take nothing for granted, and which will allow any peculiarities or unexpected laws in physical growth, etc. to show themselves.

I am at present working upon the following, for which, however, no special originality is claimed: I endeavor to secure, from as many gymnasia in the country as will co-operate with me, the measurements of those individuals who have lived, as far as may be ascertained, under approximately ideal conditions of work, and rest, and food for a term of years. These I propose to tabulate, forming a table which will appear somewhat like the percentile, but in which the mean of the individuals of each group in height will be taken, all tabulated together in the construction of the central class alone. Thus, if there are differences in structure they will show themselves. If there are not they will not. I shall not expect by this to get an ideal standard. I do expect, however, to get a standard which will be very much nearer the ideal than we could get by tabulating the measurements of a great number of individuals, nearly all of whom are confessedly below par in most respects.

In the brief discussion of the above paper it was evident that the impression was given that a general criticism of the percentile system was intended. I had no such thought in mind, for I recognize that in this method we have a way at arriving at many facts that are otherwise beyond us. What I did intend to criticise was, 1st, the assumption that the measurements of an individual should fall in a straight line on one of these charts; and, 2nd, that this should be taken to be the standard of perfection in form.